

## FINAL REPORT

AD-A183 159

ARPA Order Number: 3469 dated 8/9/77  
Contractor: Decisions and Designs, Inc.  
Contract Number: N00014-78-C-0100  
Effective Date of Contract: 1 October 1977  
Expiration Date of Contract: 31 December 1978  
Principal Investigators: C. W. Kelly; C. R. Peterson  
Telephone Number: (703) 821-2828  
Short Title of Work: Advanced Decision Technology  
Reporting Period: 1 October 1977 - 31 December 1978

WORK UNIT NR 197-045

1. Contract Objective

➤ The general objective of the work performed under the contract was to develop, evaluate, and transfer to operational use advanced decision-aiding technologies designed to assist defense decision makers in the logical solution of decision problems involving uncertainty, complexity, and dynamic effects. More specifically, the objectives were to:

- Advance the knowledge base bearing on human decision processes through relevant basic research in such disciplines as psychology, mathematical logic, operations research, artificial intelligence, and organizational behavior.
- Develop decision aids oriented toward the needs of decision makers for application in operational decision situations.
- Conduct pilot applications of decision aids in which decision analysts and operational personnel assess the capability and suitability of promising decision-aiding technologies.

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- o Conduct formal evaluations of decision aids to quantify, insofar as possible, their operational utility, *and*
- o Effect transfer and sustaining institutionalization of advanced decision technology into the ongoing decision-making processes of operational organizations. ←

## 2. Summary of Accomplishments

Descriptions of specific accomplishments toward meeting the contract objectives are listed in Appendix A, the Research and Development Status Reports covering the four quarterly periods 1 October - 31 December 1977, 1 January - 31 March 1978, 1 April - 30 June 1978, and 1 July - 30 September 1978.

Specific accomplishments attained during the remainder of the contract period include the following:

- o As a pilot application of the technology, a five-day course of instruction entitled "Decision Analysis for Intelligence Analysts and Managers" was developed for the Office of Training, Central Intelligence Agency. The course was presented by three DDI instructors during the week of 4 December 1978. There were 23 attendees drawn from the CIA, the Defense Intelligence Agency, and various other intelligence agencies that comprise the Intelligence Community.

The course was so well received by the students and CIA training officials that the Office of Training proceeded to fund two follow-on presentations of the course. One was conducted

during April 1979 for 25 senior analysts and the other is scheduled for presentation during September 1979. The funding action by the Office of Training is direct evidence of technology transfer and institutionalization.

- o Field evaluation activities continued at Headquarters, EUCOM and its three component commands of the Army, Navy, and Air Force in Europe. The field activities included reviews of user-developed decision models and progress to date, and presentations and discussions of user-suggested improvements that might facilitate man-machine interaction with the aids.
- o Considerable progress was made in the area of consolidating and integrating the application of decision-analytic techniques to cost-benefit analysis for the Armed Forces. More specifically, the accomplishments focused on the difficult problem of allocating scarce monetary resources to support the requirements, concepts, plans, and programs comprising the annual Program Objectives Memorandum (POM) submission by the U.S. Army and U.S. Marine Corps.

A number of briefings on this innovative and useful methodology for structuring the POM were presented to high-level military and civilian officials of the Department of Defense and other government agencies. The background, theory, practical application, results, and conclusions have been published as the following reports:

Buede, Dennis M. Cost-Benefit Analysis Applied to the Program Objectives Memorandum (POM). Technical Report TR 78-9-72. McLean, Virginia: Decisions and Designs, Incorporated, November 1978.

Buede, Dennis M.; Donnell, Michael L.; Feuerwerger, Phillip H.; and Ragland, Janice E. Applications of Decision Analysis to the U.S. Army Affordability Study. Technical Report TR 78-10-72. McLean, Virginia: Decisions and Designs, Incorporated, December 1978.

- o Several significant advances were made to the body of knowledge concerning human decision processes. For example, as perhaps its primary goal, decision analysis strives to ensure that the ultimate decision choice is logically consistent with the decision maker's personal value (utility) structure and judgment concerning the likelihoods of the uncertainties (probability) involved. However, the methodology of decision analysis does not provide explicit assistance in resolving demonstrated incoherence in the decision maker's specifications of the values of utility and probability. Furthermore, in all important decision situations, the decision maker's judgment is significantly influenced by various kinds of estimates (fact and opinion) prepared by the internal staff and external sources. Despite the best intentions of those who prepare such estimates, there may be limits on credibility, and the decision maker should take those into account.

Research conducted in both of these areas is described in the following reports:

Brown, Rex V. On the Credibility of Estimates: Its Evaluation and Improvement. Technical Report TR 78-6-72. McLean, Virginia: Decisions and Designs, Incorporated, June 1978.

Brown, Rex V., and Lindley, Dennis V. Reconciling Incoherent Judgments (RIJ) - Toward Principles of Personal Rationality. Technical Report TR 78-8-72. McLean, Virginia: Decisions and Designs, Incorporated, July 1978.

In addition, basic research was conducted in the related areas of how decision makers interpret a stream of incoming information, as in the case of a command and control system during a crisis situation. Such an interpretive process involves not only judgment as to the specific causes of the new information, but also judgment as to the degree of confidence concerning the presumed cause. Those issues were investigated and are discussed in the following technical reports:

Fischhoff, Baruch, and Slovic, Paul. A Little Learning ...: Confidence in Multicue Judgment Tasks. Technical Report PTR-1060-78-6. Eugene, Oregon: Decision Research, a Branch of Perceptronics, June 1978.

Shaklee, Harriet, and Fischhoff, Baruch.

Discounting in Multicausal Attribution:  
The Principle of Minimal Causation.

Technical Report PTR-1060-78-8. Eugene,  
Oregon: Decision Research, a Branch of  
Perceptronics, August 1978.

Finally, those who are indirectly as well as directly involved in the overall decision process must make certain recommendations and subsidiary decisions in support of the primary decision. Research performed in this area indicates that the criteria most people use to evaluate contributing events and explain them to others (e.g., decision makers) are often inappropriate. The research is reported in the following publication:

Fischhoff, Baruch, and Fulero, Solomon. What Makes a Good Explanation? Technical Report PTR-1060-77-11. Eugene, Oregon: Decision Research, a Branch of Perceptronics, November 1977.

- o A list of all of the technical reports produced under the contract appears in Appendix B, List of Contract Publications.
- o Under the technology transfer and sustaining institutionalization objective, a comprehensive report was prepared that describes the initial concept, major objectives, technical need, evolution, scientific and technical results, and technology transfer accomplishments achieved during the six-year span of the Advanced Decision Technology Program. The report is currently in press, with publication expected during July 1979.

APPENDIX A  
RESEARCH AND DEVELOPMENT STATUS REPORTS

R&D STATUS REPORT  
for the period  
1 October 1977-31 December 1977

ARPA Order No.: 3469 dated 8-9-77

Contractor: Decisions and Designs, Incorporated

Contract No.: N00014-78-C-0100

Effective Date of Contract: 1 October 1977

Expiration Date of Contract: 30 September 1978

Principal Investigators: C. W. Kelly; C. R. Peterson

Telephone No.: (703) 821-2828

Short Title of Work: Advanced Decision Technology

Reporting Period: 1 October 1977-31 December 1977

1. Description of Progress:

During the past quarter, pilot application activities were focused on decision aid applications in Headquarters, EUCOM and subordinate Commands, on structuring a multi-attribute utility assessment model to aid the U.S. Military Academy in formulating and measuring optimal responses to the West Point study group's recommendations, and on advancing the POM and combat readiness models.

With regard to decision aid pilot applications at Headquarters, EUCOM and the subordinate Commands, one trip was made to the Commands involved to monitor progress, to assist in modeling activities and to train additional personnel in the dynamics and use of the decision-aiding software. The decision aids are in active use on a day-to-day basis, and user reaction remains favorable. In further confirmation of this, a meeting of personnel from the European Commands involved in the pilot application activity was convened in November 1977 to evaluate progress under the program and to consider future needs and courses of action. The user group endorsed the utility of the decision aids and initiated a formal statement of Required Operational Capability (ROC) detailing a requirement for on-line decision aids and continued R&D toward improved decision-aiding capabilities.



Activities continued during the past quarter to refine and extend the capabilities of the resource allocation model (POM) developed for the Marine Corps and the combat readiness assessment model (also developed for the Marine Corps). With respect to the resource allocation model, work was focused on refining the software for greater user convenience, and on extending the capability of the model to encompass budgeting choices in the O&M and RDT&E areas. Work on the readiness assessment model was focused on refining the software into final form for USMC use.

A new pilot application activity initiated and substantially advanced during the past quarter was concerned with the application of multi-attribute utility assessment methods to the problem of aiding the U.S. Military Academy in determining optimal courses of action in response to the set of recommendations put forward by the West Point study group. This pilot application was undertaken as a two-phase effort with the first phase focused on modeling a subset of the total problem and the second phase, conditional on acceptance of the Phase I methodology demonstration, concerned with completion of a comprehensive model and implementation of it on an IBM 5100 computer. The Phase I milestone was successfully passed in November 1977, and work progressed through development of a complete model structure and prototype implementation of the model on an IBM 5100 computer. Value and probability elicitation for the model nodes are in progress. When this model is completed and placed in operation, the U.S. Military Academy will have an on-line performance measuring capability--a unique and valuable capability for an organization lacking the conventional dollar metric.

In the task area concerned with curriculum development, work advanced on schedule. Decision analysis training materials in the form of annotated outlines (supported by supplemental readings and audio cassettes) were advanced to approximately 75% of completion during the quarter. These materials will be used in a course of instruction to be offered at the U.S. Marine Corps Command and Staff College. Based on the experience derived from the Staff College offering, the training modules will be modified and refined as necessary for use by other DoD training institutions. As a matter related to dissemination of information about decision-aiding methodology, the Handbook for Decision Analysis, which was extensively revised and refined during FY 1977, was completed and published during the past quarter. We expect this document to be in heavy demand. Its widespread dissemination should yield highly leveraged results toward goals of technology transfer.

In the basic research portions of the program, work moved ahead essentially on schedule on an array of topics

consistent with those proposed. Research areas under study included: Bargaining and negotiation strategies, decision making in long-term investment contexts (as in defense R&D commitments), reliability considerations in MAU models, the trade-off between modeling error and elicitation error in MAU applications, formal decision models for crisis decision making, calibration of probability assessors, and work on the psychology of explanation.

The only significant schedule deviation involved the work planned by the Stanford Research Institute. Due to delays in contract implementation, the SRI group was not active on this project during the reporting period. At the time of this writing, contractual arrangements have been completed and work is now underway. In spite of the start-up delay, no difficulty is anticipated in completing the proposed work on schedule.

2. Change in Key Personnel:

None

3. Summary of Substantive Information Derived from Special Events:

During the past quarter, one trip was made to Headquarters, EUCOM and subordinate Commands to monitor progress of the pilot application activities in progress at those commands. Three trips were made by DDI personnel to the U.S. Military Academy, West Point, in conjunction with the West Point modeling activity discussed in Part 2 of this report. Plans were made for a two-day meeting on 10-11 January of all participants in the Advanced Decision Technology Program. The meeting is intended to serve a program review function and to stimulate idea exchange and program planning.

4. Problems Encountered and/or Anticipated:

None

5. Action Required by the Government:

None

6. Fiscal Status:

(1) Amount currently provided on contract:	\$1,223,709
(2) Expenditures and commitments to date:	\$ 893,218
(3) Funds required to complete work:	\$ 330,491

R&D STATUS REPORT  
for the period  
1 January 1978-31 March 1978

ARPA Order No.: 3469 dated 8-9-77

Contractor: Decisions and Designs, Incorporated

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Effective Date of Contract: 1 October 1977

Expiration Date of Contract: 30 September 1978

Principal Investigators: C. W. Kelly; C. R. Peterson

Telephone No.: (703) 821-2828

Short Title of Work: Advanced Decision Technology

Reporting Period: 1 January 1978-31 March 1978

1. Description of Progress:

During the reporting period 1 January 1978 through 31 March 1978, significant progress was made in the Advanced Decision Technology Program. The major pilot application activity at Headquarters, EUCOM and subordinate commands continued into its final quarter of direct ARPA support. A wrap-up visit to the participating commands was made in March 1978. It was observed that at Headquarters, EUCOM, USAFE, and USAREUR, frequent day-to-day use continues to be made of the decision-aiding capabilities emplaced at those Headquarters. At CINCUSNAVEUR, however, the situation is not as encouraging. There, rapid rotation of the personnel trained in the use of the decision aids has brought the effort to at least a temporary standstill. The latter circumstance underscores the necessarily long time course of technology transfer, the desirability of longer term support of transfer activities, and, in broader perspective, lends endorsement to those special activities within the program focused on institutionalizing the new methodology, viz curriculum material for DoD professional schools and publications such as the Handbook for Decision Analysis.

In other applied areas, the OPINT software, useful for rapid assessment of decision options, was extensively revised during the past quarter. In its revised form, the software now runs on the IBM 5110 computer (four times as fast as the

5100) and incorporates rationale-capturing provisions, improved sensitivity test routines, and greatly expanded tutorial assistance features. These changes were all in response to needs expressed by users at Headquarters, EUCOM and subordinate commands.

Also during the past quarter, applied efforts focused on the development of models to aid the U.S. Marine Corps in assessing unit combat readiness and in making resource allocation choices in conjunction with the annual Program Objective Memorandum (POM) process were completed. Both of these models are now considered sufficiently refined and stable to merit formal documentation for implementation by users. As a related matter, it is worth noting that a companion effort to the USMC POM effort was funded by the U.S. Army, building upon methodological and software developments of the ARPA-supported Advanced Decision Technology Program. This constitutes yet another example of highly leveraged technology transfer.

Curriculum development activities initiated in the last quarter of CY 1977 were also completed during this reporting period. Prototype curriculum materials were developed to convey decision-analytic methodology to the USMC Command and Staff College at Quantico. Fifteen lectures were presented, supported by the curriculum material, and were apparently well received. This curriculum and its presentation at Quantico is a forerunner of what we hope will be widespread application throughout DoD professional schools of refined curriculum material on the same subject.

In those portions of the program concerned with basic research on decision processes and decision-aiding methods, work moved ahead as planned. Active projects during the past quarter included: research (via simulation) on the trade-off between modeling error in multi-attribute assessment situations, research on simplified weighting schemes (e.g., the use of rank weights) in MAU applications, experimental work on the validity of utility elicitation methods, and completion of an experimental design for research on the role of expertise in probabilistic inference. Other active projects included: work on bargaining and negotiation strategies, decision making in situations involving very-long-term time horizons, completion of a draft report on the circumstances leading to overconfidence in estimates, preparation of a draft theoretical paper on contextual influences on the veridicality of probability estimates, initiation of research on a potential debiasing procedure (requiring people to consider conflicting reasons to support or deny a judgment), and completion of an experimental design to assess how well people can rank and value alternative multiple outcomes in a decision context.

2. Changes in Key Personnel

None.

3. Summary of Substantive Information Derived from Special Events

On 10 and 11 January 1978, a meeting was held at DDI attended by all principal participants in the Advanced Decision Technology Program. The meeting was convened to serve a program review function and as a forum for idea exchange and program planning. As in the past, this meeting was highly successful in meeting its objectives. While the technical interchange was generally stimulating, a particularly fruitful discussion focused on the issue of modeling versus elicitation error. At issue is the degree to which one can use simple additive models in situations where dependencies call for complex multiplicative models. The complex multiplicative model is more time-consuming to apply and entails more numerous judgments as input. The question is whether or not the increased modeling accuracy is washed out by judgmental error. The debate prompted an experimental plan on the part of Professor Edwards to test the proposition through an extensive series of simulation studies. The initial work in this area is now underway.

4. Problems Encountered or Anticipated

None.

5. Action Required by the Government

None.

6. Fiscal Status

(1) Amount currently provided on contract:	\$1,533,292*
(2) Expenditures and commitments to date:	\$1,211,022
(3) Funds required to complete work:	\$ 322,270

\*Including pending contract modifications.

R&D STATUS REPORT  
for the period  
1 April 1978-30 June 1978

ARPA Order No.: 3469 dated 8-9-77  
Contractor: Decisions and Designs, Incorporated  
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Effective Date of Contract: 1 October 1977  
Expiration Date of Contract: 30 September 1978  
Principal Investigators: C. W. Kelly; C. R. Peterson  
Telephone No.: (703) 821-2828  
Short Title of Work: Advanced Decision Technology  
Reporting Period: 1 April 1978-30 June 1978

1. Description of Progress

During the past quarter, the principal pilot application work within the Advanced Decision Technology Program was focused on the use of decision analytic tools to assist the Army in the complex resource allocation choices fundamental to preparation of the Army Program Objectives Memorandum document (POM). Cost benefit methodology reflected in the resource allocation software package (RAM) was used to assist the Army in completion of the first phase of their POM activity involving the development of Program Development Incremental packages (PDI) for consideration by OSD.

As part of the POM effort, the resource allocation software package, previously operable on the IBM 5100 computer, was reprogrammed to operate on the more advanced IBM 5110 computer. The new software/hardware configuration quadruples the speed of operation and affords greatly increased display formatting capability.

At the time of this writing, POM activities are at a standstill pending receipt by the Army of any issues that might be raised by OSD over the PDI package. At that time (August and September 1978), activities will be resumed to assist the Army in preparation of its final POM submittal.

In the basic research portion of the program, research activities proceeded on a wide range of topics. An additional experiment was completed during the past quarter on the use

of marker events to aid assessors in estimating very low probabilities. As in an earlier experiment, the research results proved to be disappointing. The marker event technique was again of little or no use in improving estimates of low probability events.

Experimental work on the assessment of group values (utilities) was completed during this reporting period. Data analysis and report preparation were underway at the conclusion of the quarter.

Research concerned with the trade-off between modeling error and judgmental error in multi-attribute utility assessment proceeded ahead of schedule with a major focus during the past quarter on the sensitivity of linear models to different weighting schemes. Within this task domain, the current emphasis is on exploring the appropriateness of a rank-exponent weighting scheme as an alternative to the much more judgmentally demanding (and time-consuming) ratio weighting procedure. Data collection and report preparation will be completed during the next quarter.

In another research area, work was initiated to develop a computer program for the 5110 computer that combines probability assessment routines with problem structuring algorithms. Such a capability will serve the valuable function of allowing decision makers to structure risky decision problems requiring subjective probabilities as inputs to the model. Other research efforts active during the past quarter concerned with decision-aiding computer software were focused on: 1) the development of computerized procedures to handle crisis decision making; 2) interactive programs to facilitate risk preference assessments; and 3) a program to facilitate the application of influence diagrams in the resolution of decision problems.

In research focused on decision flexibility, progress over the past quarter included definition of a Bayesian decision model for studying the effects of a variety of decision parameters on decision flexibility. Using the model, preliminary calculations were made of optimal decision flexibility (reserves) as a function of four different parameters. This work will be completed and move to press during the next reporting period.

Work also proceeded as scheduled during the past quarter on the task concerned with the revision and publication of a probability encoding manual. New sections updating the original draft were completed and the complete text was entered into a word-processing system for convenient editing and set-up for publication.

Technical dissemination efforts were also actively pursued during the past quarter. At least eight technical reports have been prepared through the first draft stage and are in various stages of progress toward formal publication. In addition, special lectures highlighting elements of the Advanced Decision Technology Program were presented to a variety of government agencies. Two lectures reviewing the ARPA-supported ADT program and highlighting inferencing procedures were presented to the staff of the Information Sciences Center, CIA. One lecture, a review of advanced decision aiding technologies, was presented to the Defense Intelligence School and another lecture on the same topic was presented to the Senior Seminar of the Foreign Service Institute.

2. Changes in Key Personnel

None.

3. Summary of Substantive Information Derived from Special Events

Not applicable.

4. Problems Encountered or Anticipated

None.

5. Action Required by the Government

None.

6. Fiscal Status

(1) Amount currently provided on contract	\$1,533,292*
(2) Expenditures and commitments to date:	\$1,481,657
(3) Funds required to complete work:	\$ 51,635

\*Including pending contract modifications.



R&D STATUS REPORT  
for the period  
1 July 1978-30 September 1978

ARPA Order No.: 3469 dated 8-9-77

Contractor: Decisions and Designs, Incorporated

Contract No.: N00014-78-C-0100

Effective Date of Contract: 1 October 1977

Expiration Date of Contract: 30 September 1978  
(Extension in Process)

Principal Investigators: C. W. Kelly; C. R. Peterson

Telephone No.: (703) 821-2828

Short Title of Work: Advanced Decision Technology

Reporting Period: 1 July 1978-30 September 1978

1. Description of Progress

DDI assisted the Army in updating the priorities of its Program Objectives Memorandum (POM) using the feedback in the Program Decision Memorandum (PDM) and the Amended PDM (APDM) of the Office of the Secretary of Defense (OSD). The PDM and APDM represent OSD's program directives within the three fiscal constraints: minimum, basic, and enhanced.

Then, to ensure that POM/PDM priorities matched the FY80 budget priorities, the Director of the Army Budget (DAB) and the Program Analysis and Evaluation Directorate (PA&ED) of Army became responsible for "crosswalking" these two sets of priorities. Whereas PA&ED's interest is functional and concerned with the five POM years, DAB's interest lies in budget appropriations for the budget year. The two groups must ensure that the implementation of a functional program is not delayed unknowingly by budget priorities. Feedback from DAB is therefore essential to PA&ED in setting POM priorities for the next year.

Technical report dissemination has continued during the past quarter. Eight technical reports were published and two others have been prepared for publication in November. The Advanced Decision Technology Program Bibliography (Enclosure 2) has been revised to include these new reports. This task may continue for several months depending on the pending request for extension of the contract.

- 2. Changes in Key Personnel

None.

3. Summary of Substantive Information Derived from Special Events

Not applicable.

4. Problems Encountered or Anticipated

An extension of the contract expiration date has been requested of the Contracting Officer, primarily to permit subcontractors to complete work.

5. Action Required by the Government

None.

6. Fiscal Status

(1) Amount currently provided on contract:	\$1,485,933*
(2) Expenditures to date:	\$1,442,700
(3) Funds required to complete work:	\$ 43,233

\*Including pending contract modifications.

APPENDIX B  
LIST OF CONTRACT PUBLICATIONS

ADVANCED DECISION TECHNOLOGY PROGRAM BIBLIOGRAPHY

Contract N00014-78-C-0100

- Brown, Rex V. On the Credibility of Estimates: Its Evaluation and Improvement. Technical Report TR 78-6-72. McLean, Virginia: Decisions and Designs, Incorporated, June 1978.
- Brown, Rex V., and Lindley, Dennis V. Reconciling Incoherent Judgments (RIJ) - Toward Principles of Personal Rationality. Technical Report TR 78-8-72. McLean, Virginia: Decisions and Designs, Incorporated, July 1978.
- Buede, Dennis M. Applications of Decision Analysis to the U.S. Army Affordability Study. Interim Technical Report TR 78-5-72. McLean, Virginia: Decisions and Designs, Incorporated, June 1978.
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- Fischhoff, Baruch, and Slovic, Paul. A Little Learning ...: Confidence in Multicue Judgment Tasks. Technical Report PTR-1060-78-6. Eugene, Oregon: Decision Research, a Branch of Perceptronics, June 1978.
- Shaklee, Harriet, and Fischhoff, Baruch. Discounting in Multicausal Attribution: The Principle of Minimal Causation. Technical Report PTR-1060-78-8. Eugene, Oregon: Decision Research, a Branch of Perceptronics, August 1978.
- Tversky, Amos, and Kahneman, Daniel. Causal Schemata in Judgments Under Uncertainty. Technical Report PTR-1060-77-10. Eugene, Oregon: Decision Research, a Branch of Perceptronics, October 1977.